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ABSTRACT

This study guide groups eleven lessons into four study units. The first unit discusses the development and basic concepts of solar heating. The second unit deals with the nomenclature of the solar heating system. The third study unit covers sizing of the solar heating system to meet demand and discusses the operation of the total system. The fourth unit presents learning materials concerning installation and servicing of solar assisted heating systems. There are review tests and unit examinations structured for assistance in reviewing the material and in integrating new information with that learned previously. (Author/RE)

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STUDY GUIDE FOR FUNDAMENTALS OF SOLAR HEATING

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Study Guide for FUNDAMENTALS OF SOLAR HEATING

a correspondence course for the airconditioning industry

January 1978

Prepared by
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For The
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and Solar Applications
Washington, DC 20545

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Major participants in formulating this publication included Dr. James J. Buffer, Jr., Dr. William D. Umstattd, Dr. E. Keith Blankenbaker, and James A. O'Brien of the Ohio State University; and James Healy (NHAW).

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This Study Guide Is Your At Home "Instructor"

Follow All Directions Carefully

Beginning Your Program: Study Hints

1. **Carefully read these twelve steps.**
   This information outlines the way your instructional program will help you learn new information and skills. These 12 steps are here to provide you with a guide on how to study and to achieve the best results from your course. We do not expect you to memorize them. You will receive additional directions and reminders of how to study as you progress through your Study Guide.

2. **Select a place to study where distractions are at a minimum.**
   A pleasant atmosphere, good light, proper temperature, a comfortable chair and desk or table, and minimal noise (no television or radio) will help you achieve better results.

3. **Read the Introduction to your Study Guide.**
   This section was written to inform you of the organization and structure of your instructional materials and the way they were developed to help you improve your learning. This is the first stage of the learning system. It is designed to help you learn how to learn.

4. **Study the Unit Previews in your Study Guide.**
   Once you begin to read the first Unit Preview, you will have entered the second stage of the learning program. These sections will give you a brief preview of the subject matter you will study in each unit of the textbook.

5. **Carefully follow the directions that immediately follow the Unit Preview.**
   The directions will provide you with the guidance and direction needed to use the textbook and Study Guide to achieve optimal benefits.

6. **Study the Learning Objectives of the Lesson.**
   This section will tell you the content of the specific lesson and will list some of the important concepts you will learn. This material will help you learn by providing you with clues on what to expect.

7. **Study the assigned textbook reading.**
   The textbook contains important technical information and concepts that were identified by specialists in the heating industry. It is your primary source of reference.

8. Immediately after reading the textbook assignment **complete the assigned Progress Review in your Study Guide.**
   The Progress Review allows you to apply your newly acquired knowledge to answer questions and solve problems. It also will assist you in clarifying any misunderstandings you have regarding the subject matter you just studied.

9. **Compare your answers with those given in the Answer Key in the back of the Study Guide.**
   This will provide you with immediate feedback of your achievement. If there is a disagreement regarding a test item answer, or if you need clarification, refer back to the textbook. If you need more help, fill out a Student Assistance Form and mail it to your instructor.

10. After you have reviewed your Progress Review and the text material, **repeat steps 5, 6, 7, 8, and 9** for the remaining assignments within the unit.

11. **Complete the Unit Examination and mail it to your instructor.**
    The results of this test will assist your instructor in evaluating your progress and achievement. The results will also be used to provide you with remedial assistance when necessary.

12. **Begin your next unit of study** immediately after mailing the Unit Examination.
    Your certificate of achievement will be mailed to you after you satisfactorily complete all the assignments in this course, the Four Unit Examinations, and Course Evaluation Form. Remember, one of the important advantages of home study is that YOU set your own pace of educational achievement. You are in control of when, where, and how you study. The school will provide you with specially developed instructional materials to HELP YOU BE SUCCESSFUL in home study. Do not hesitate to write whenever you need assistance. Good Luck!

Instructional Staff

COURSE OBJECTIVES

For the purposes of developing this training course, a heating and air conditioning technician is identified as a person who may sell, design, specify and/or supervise the installation of ordinary residential and light commercial heating and air-conditioning systems involving the use of recognized standard components.

The essential training objective of this course is to provide the heating and air-conditioning technician with fundamental technical knowledge on solar assisted heating in order that the technician may acquire and advance in design, installation and servicing responsibilities as the market for solar assisted heating progresses.

Upon the completion of the course, the student technician should be able to:

1. Identify and understand the function of all the components in both air and hydronic solar assisted heating systems using flat plate collectors.
2. Size and layout all the typical solar components used in residential or light commercial solar systems with guidance and assistance from component manufacturers.
3. Assist in planning and supervising the installation of solar components in residences and other lightly constructed buildings with no unusual occupancy requirements.
4. Assist in troubleshooting common solar assisted heating operational problems.

In preparing this material, it has been assumed that the student technician: 1) understands basic heating industry terminology; 2) has knowledge of heat loss calculation procedures; and 3) knows simple duct and pipe sizing techniques, as presented in recognized courses in Fundamentals of Heating, Heating & Cooling System Design and Modern Hydronic Heating, or as normally accquired by practical experience "on the job" in the industry.

Mastery of these training objectives will be demonstrated by successful completion of four written "units" examinations during the training period.

Fundamentals of Solar Heating

Introduction

You are about to join thousands of other ambitious people who have found correspondence study a most efficient and rewarding way of continuing their education. The fact that you have chosen to enroll in a home study educational program indicates that you realize the importance of continuing your education. Technological advances are creating many new jobs in business and industry, as well as eliminating some. More than ever before, men and women are finding that "continuing education" is becoming a must if they are to keep pace with increasing industrial and technical changes.

Home study is being used successfully by large numbers of people in the professions to *update* their knowledge of a field of study as well as a means of learning *new* subject matter. Many businesses and industrial companies encourage their employees to enroll in correspondence programs as a convenient means of maintaining and improving professional skills.

Much research and effort has been put forth to develop a program of study which will assist you in achieving your desired goal of self-improvement. All of your instructional materials have been written and designed to HELP YOU TO LEARN!

Your educational materials consist primarily of a specially created textbook, *Fundamentals of Solar Heating*, and a *Study Guide*.

The textbook was edited by Dr. James J. Buffer, Professor, Industrial Technology, The Ohio State University and James H. Healy, Director of Education, Northamerican Heating and Airconditioning Wholesalers Association.

You will be learning new information from your textbook much the same as you would in a regular classroom school except that you will do it at your own pace in the convenience of your own home.

The *Study Guide* has been developed by professional educators to help you learn more efficiently and effectively. The *Study Guide* is designed to provide you with immediate confirmation or correction of your understanding of the subject matter.

How Does The Instructional System Work?

The two books are designed to serve as a "programmed" instructional system which will provide you with immediate *feedback* about your success in understanding and/or applying the learned information. The *Study Guide* assumes the role of a "substitute" teacher for the home study student. Thus, it provides you with the necessary guidance and direction to help clarify, apply, understand, and reinforce your learning activities.

There are review tests and unit examinations, structured so that they assist you in reviewing the material just studied and in integrating new information with that learned in previous lessons. The unit examinations will also serve as a diagnostic and evaluative tool for your instructor.

The main purpose of the review tests and unit examinations is to determine whether you have attained the desired goals or purposes of the course. Your instructor will use the results of the unit examinations to provide you with further instruction and remedial assistance whenever necessary.

How To Use The Study Guide

A brief introduction to each unit of study is presented in your *Study Guide*. A unit of study is merely a collection of several closely related assignments.

A preview of each assignment is also included in your *Study Guide*. It contains the general purpose of the textbook section and what you should be able to do after studying the section. Generally, after reading a specific unit preview, you will be referred to an assignment in your textbook.

Progress Review

After completing each textbook reading assignment, you will be asked to complete a Progress Review in your *Study Guide*. It is important that you first *attempt* to answer the review questions *without* the assistance of your textbook. After you complete *all* of the items, check your answers with those listed in the Answer Key located in the back of this *Study Guide*. If you selected a wrong answer, or if you were unable to understand a question, refer back to the textbook. Re-read this page and study the information until you understand why the answer listed in your *Study Guide* is the best response or solution to the question. DO NOT RETURN THIS ASSIGNMENT FOR GRADING.

If, after following these steps, you still are unable to understand a question or find the appropriate solution to a problem, complete one of the Student Assistance Forms provided in your course package and mail it to the Manager of Student Services. Please, BE CERTAIN TO PROVIDE ALL OF THE INFORMATION REQUIRED ON THE FORM, so that you may be given appropriate assistance.

Unit Examination

After you have satisfactorily completed several Progress Reviews and the necessary reading and review of the text material, you will be asked to complete a Unit Examination. The answers to the examinations are *not* included in your *Study Guide*. Also, you should *not* refer to your textbook to find the answers to questions in the Unit Examination. Remember, these tests are part of your instructional program. They are designed to provide your instructor with some information regarding your progress. This means of evaluation will assist your teacher in providing additional instruction and assistance to help improve your educational growth. Your unit examination paper MUST BE RETURNED for review by your instructor.

Your Study Schedule

Your course is divided into four units of study. As a rule of thumb, you should devote approximately three weeks to each unit. Therefore, on the average, a student should be able to complete this course in about twelve weeks. However, some students may complete the course in less time, and a few students may need more time because of unusual work schedules or personal responsibilities. This is one of the real advantages of home study—THE STUDENT CAN SET HIS OWN WORK PACE.

Now Turn The Page For Your Unit I Preview

PREVIEW OF UNIT ONE

The first unit of this course consists of the first two lesson of the textbook. Lesson One, *Solar Heating and Cooling*, explains the basic concepts, system components, system types, and economic considerations involved with Solar Energy. As you progress through this lesson, you will be introduced to the major components which comprise a system together with different types of systems. You will develop a sense of the advantages and disadvantages of these types of systems as they apply to various applications. Because of their newness, it is also important that you gain an awareness of the economic implications involved with solar systems: their initial cost and their possible long term economic payback. A final consideration in this introductory lesson concerns climatological considerations, a topic of importance to you since the climate for a given area has a direct effect on the cost of the system.

Lesson Two, *Solar Radiation*, is written to increase your knowledge of the energy source you plan to utilize: the nature of solar radiation and the composition of solar rays. Since, as one would expect, different people measure the same item in different ways (and this area of study is no exception). These differences of measure will be explained together with techniques to convert the measures into a known standard. This ability to understand measures of radiation will help you determine and comprehend just how much solar energy can be expected to reach a given spot on earth over a given period of time. Once these data are covered, you will learn how radiation varies in its concentration as seasons pass and weather conditions change. How to take optimum advantage of the radiation received is then discussed.

The importance of these first two lessons lies in your ability to understand the impact of solar energy at this historical point in time together with the equipment and technology that is available to utilize it. Later lessons will cover much of these data in greater detail. Mastery of this portion of the course will enable you to progress through later lessons with greater assurance.

As you continue through this course, keep in mind that the purpose of the lessons is to provide you with *knowledge* so you can *develop* an *understanding* about solar heating systems. Therefore, do *not* just study to pass the course—study to become a competent representative of the heating and cooling industry.

LESSON ONE
Learning Objectives

Lesson One, *Solar Heating and Cooling*, explains the basic concepts, structure, and economic considerations involved with solar heating and cooling. The lesson is designed to be a comprehensive introduction which will permit an overall understanding, together with some insight, to the economic implications involved with these systems.

To fully and effectively complete this overview, you should try to achieve the following goals:

1. Name the major components of a solar heating and solar cooling system.
2. Distinguish the differences between air and liquid systems.
3. Identify the differences within the component groups.
4. Describe what types of systems have practical value as opposed to systems under development with possible future promise.
5. Explain the difference between active and passive solar heating.
6. Describe the basic expectations of performance of different types of systems.
7. Recognize the advantages and disadvantages of the various types of components within a system.
8. Identify and describe the economic implications of solar heating and solar cooling.
9. List all the items involved in costing a system.
10. Name the climatological characteristics which are involved in sizing a solar heating/solar cooling system.
11. Explain how the availability and cost of conventional fuels will impact on solar heating/solar cooling.

GO TO YOUR TEXTBOCK STUDY LESSON 1

LESSON ONE
Progress Review

Study Lesson One in your textbook before you attempt to complete this review.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

T F 1. A solar heating and/or cooling system is any system which utilizes solar energy as source of heat.

T F 2. A passive system usually has no moving parts and is not the major concern of the people taking this course.

T F 3. A concentrating solar collector best utilizes diffuse solar radiation.

T F 4. The insulation beneath the absorber plate helps produce a quieter operating solar collector.

T F 5. Like flat plate collectors, concentrating collectors can operate in any weather conditions so long as minimal light conditions exist.

T F 6. An R-10 insulation rating is more than adequate for the surfaces of liquid thermal storage units.

T F 7. Insulation material on the bottom of a 6' water storage tank must withstand a compression weight of 280 pounds per square foot.

T F 8. Packing and/or side wall stress is not a problem in a pebble-bed heat storquid solar system.

T F 9. A good quality steel tank will not be subject to any problems during the life of the system.

T F 10. While a solar air system requires lower capital costs, more electric energy is required during its life to move the heat from the collector to storage to use as compared to a liquid solar system.

T F 11. Liquid solar systems have a long history of working well and the critical cost is low.

T F 12. A heat pump could be considered as an auxiliary heat supply in some areas of the country.

T F 13. Of the absorption refrigeration currently in use, the Lithium-Bromide chillers appear to hold the most promise.

T F 14. Through the use of a Solar Rankine-Cycle Engine, a device such as a heat pump could become a solar related device even in its cooling cycle.

T F 15. The cost of conventional energy (gas, oil, etc.) should level off within the next five years.

T F 16. The amount of solar radiation available during the heating season is a major economic consideration for a solar heating system.

T F 17. Currently, electricity is the best fuel to buy in terms of cost per million Btu's throughout the country.

T F 18. Property taxation rate and loan interest rate are just two of the items which must be considered when costing a solar heating system.

T F 19. Except for minor differences, cities along the same latitude have equal solar Btu's available to them.

T F 20. Snow is not as much of a consideration when planning a solar energy system for Flagstaff, Arizona as for Boston, Massachusetts.

Fill in the blanks with the word (or words) which most accurately completes the thought.

21. The two basic types of solar energy systems are called active and _____.

22. A roof monitor, a south-facing window, and a _____ are all examples of passive solar collectors.

23. The two basic types of solar collectors are _____ or _____.

24. The absorber plate is usually _____ in color which aids in _____ the solar radiation.

25. Solar collectors tend to lose heat through _____, _____, and/or _____

26. The layer of still air between the glass and the absorber acts to reduce _____ loss.

27. Because of their size, air thermal storage units are normally placed into the building _____ construction.

28. Round pebbles _____ to _____ in size are ideal for a pebble-bed heat storage unit.

29. If a horizontal pebble-bed heat storage unit is used, the height of the unit must not exceed _____.

30. Water heat storage units are subject to _____, especially at the _____ _____.

31. Two types of auxiliary electric heat in solar heating systems are _____ _____ or _____ _____ _____ or both.

32. For cooling residential building, solar energy is only directly useful in _____ methods.

33. In terms of realistic economics, only the _____ system appears to be practical for solar cooling, at least into the early 1980's

34. A heat pump is a mechanical vapor-compression system consisting of a _____, _____, _____ _____ and an _____.

35. A prototype solar heating system, using circulating air, has been operational since 1957 with _____ major problems and essentially no _____ costs.

36. Solar heating should provide _____ percent of the annual heating requirements to be practical and economical.

37. Considerations that may influence users toward solar heating are:
    1. Incorporation of systems into _____ _____.
    2. First costs versus _____ _____ _____
    3. Ease of _____ and _____.
    4. _____ and reliability.

In the following multiple choice questions, choose the phrase which *most correctly* completes the statement and circle the corresponding letter in front of the phrase.

38. Which item is *NOT* a component of an all-air solar heating/solar cooling system?

    a. auxiliary furnace.
    b. heating/cooling distribution system.
    c. solar collector.
    d. boiler.
    e. cooling unit.
    f. thermal storage unit.

39. Of the cooling systems listed below, indicate which is currently available for residential solar cooling.

    a. Evaporative Cooling Through Rock Bed
    b. Munter's Environmental Control
    c. Thiethylene Glycol Open Cycle Disceccant System
    d. Radiative Cooling

40. Based on the factors presented in this unit, it is essential that solar heating/solar cooling systems provide the user with:

    a. comfort and safety.
    b. maximum return for dollar invested.
    c. a good looking exterior to the building.
    d. snob appeal.

Compare your answers with those given in the answer key in the back of this *Study Guide*. If you have any question regarding the correct response to a review item, refer to your textbook for clarification. (See Study Hint No. 9.)

DO NOT RETURN THIS REVIEW QUIZ FOR GRADING

LESSON TWO
Learning Objectives

Lesson II, *Solar Radiation,* explains what this course is all about—the use of the solar energy which reaches earth for heating and cooling. In this lesson, you will discover the way energy given off by the sun is altered before it reaches the earth, and how the energy that does reach the earth can be best utilized. Thus, your objective will be to recognize the factors which affect the availability of solar radiation at the earth's surface.

To fully and effectively complete this lesson, you should try to achieve the following goals:

1. Recognize those conditions—for example, clouds, dust, and other atmospheric pollutants; shading from trees & buildings; and collector orientation and tilt—which affect solar energy reaching the collector.

2. Describe the difference between direct and diffuse radiation.

3. Recognize the various units of measure used to report solar radiation.

4. Convert solar radiation from one unit of measure to another using standard conversion factors.

5. Determine the amount of solar radiation available for a given period of time.

6. Describe the effect of seasonal variations.

7. Recognize the importance of hourly variations.

8. Learn and locate sources of solar data.

9. Select the data needed for planning a solar system.

10. Blend the information learned in lessons I and II into a singlular unit of knowledge.

GO TO YOUR TEXTBOOK STUDY LESSON TWO

LESSON TWO
Progress Review

Study Lesson Two in your textbook before you attempt to complete this review.

Please indicate whether the following statements are true of false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

T F 1. The sun's energy can be converted from electromagnetic waves to heat.

T F 2. The sun is approximately 93 million miles from earth.

T F 3. The earth's inhabitants are not all that interested in solar energy.

T F 4. Infrared radiation waves are long.

T F 5. The sun produces the greatest amount of energy in the visible range.

T F 6. A solar collector absorbs radiation from two of the three radiation regions of interest to this course.

T F 7. The upper atmosphere, clouds and dust all contribute to scattering solar radiation.

T F 8. Solar energy on a horizontal surface will show month to month variations.

T F 9. Solar rays must pass through a larger thickness of atmosphere in the early morning.

T F 10. The exposure of solar energy on vertical surfaces is the same as the exposure on horizontal surfaces.

T F 11. Of greatest use is knowing the expected monthly radiation on a surface during the period of the heating season.

Fill in the blanks with the word (or words) which most accurately completes the thought.

12. It is to the sunlight that was received in past ages that we owe the existence of our _____ fuels.

13. The three types of solar rays which are of interest to this course are _____, _____, and _____.

14. The abbreviation of British Thermal Units per square foot is _____.

15. To convert Langleys into Btu/ft^2, multiply by _____.

16. UV is the abbreviation for _____.

17. Infrared is abbreviated _____.

18. Materials with a temperature below 800°F emit only _____ radiation.

19. In the winter, the sun is _____ in the sky than in the summer, and the resultant angle _____ the amount of radiation intercepted on a flat surface.

20. The amount of energy intercepted by a horizontal surface is much _____ as the angle (height) of the sun increases.

21. Generally speaking, the angle of the sun above the horizon at noon is about _____ in the winter and _____ in the summer for latitudes near 40°N.

22. The greatest intensity of solar radiation occurs during the _____ _____ hours.

23. North wall exposure to direct solar radiation is not important to people living in the _____ hemisphere.

24. In the northern hemisphere, the solar collector is aimed _____.

25. As a general rule, a solar collector used for heating only should have a tilt equal to the _____ plus _____ degrees.

26. A solar collector can be oriented _____ east or west of due south without any serious effect on its collecting ability.

27. A solar collector oriented 15 degrees to the east of due south will _____ the time of peak collection by _____ hour.

In the following multiple choice questions, choose the phrase which *most correctly* completes the statement and circle the corresponding letter in front of the phrase.

28. The earth offers the sun what quality of target to absorb its radiation?

    a. Very good
    b. Average
    c. Very small
    d. None of the above

29. If the amount of solar radiation received by the earth were reduced,

    a. nothing would happen.
    b. the earth would freeze.
    c. the earth would boil.

30. The surface temperature of the sun is approximately

a. 5,000°F.
b. 10,000°F.
c. 15,000°F.
d. 20,000°F.

31. Langley/min is the abbreviation for

a. calories per square centimeter.
b. the 47 second minute named after Carl Langley.
c. calories per square centimeter per minute.
d. both a and c.

32. The solar constant is equal to

a. 1.940 Langley's/min.
b. 428.7 Btu/(ft^2 h)
c. both a and b
d. none of the above

33. When someone says that an air conditioner is rated at one ton, they mean

a. the unit will produce the same Btu's of cooling as melting one ton of ice in one day.
b. the air conditioner weighs one ton.
c. the unit will cool one ton of anything for a day.

34. To tilt the solar collector so that it is perpendicular to the sun's rays is

a. advantageous.
b. expensive.
c. a waste of time.
d. all of the above.

Compare your answers with those given in the answer key in the back of this *Study Guide*. If you have any question regarding the correct response to a review item, refer to your textbook for clarification. (See Study Hint No. 9.)

DO NOT RETURN THIS REVIEW QUIZ FOR GRADING

Remove this Exam
from your Study Guide

Score _____

Grade _____

Instructor _____

Date _____

DO NOT WRITE IN THIS SPACE

Fundamentals Of Solar Heating
UNIT ONE EXAMINATION

Student's Name _____

Address _____ City _____ State _____ Zip _____

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

T F 1. The two basic types of solar energy systems are called active and passive.

T F 2. The two basic types of solar collectors heat metal or liquid.

T F 3. The absorber plate is usually silver in color which aids in reflecting the difuse solar radiation.

T F 4. Solar collectors tend to lose heat through leaks, a high R factor, and convection.

T F 5. Because of their size, air thermal storage units are normally placed into the building after construction.

T F 6. For cooling residential buildings, solar energy is only directly useful in cooling methods using refrigeration cycles.

T F 7. A prototype solar heating system, using circulating air, has been operated since 1937 with no major problems and essentially no maintenance costs.

T F 8. Solar heating should provide 50-80 percent of the annual heating requirements to the practical and economical.

T F 9. It is to the sunlight (solar energy) that was received in the past ages that we owe the existence of our atomic fuels.

T F 10. To convert Langleys into Btu/ft^2, multiply by 221.

T F 11. Materials with a temperature below 800°F emit only infrared radiation.

T F 12. Radiation is termed direct radiation if it has not been scattered by clouds and dust and diffuse if it has.

T F 13. The sun's position in our sky varies because, as the earth follows its orbit, the tilt of the earth's axis changes our relationship with the sun.

T F 14. The greatest intensity of solar radiation occurs during the early morning hours when the air is cleaner.

T F 15. As a general rule, a solar collector used for heating only should have a tilt equal to fifteen degrees plus latitude.

T F 16. The optimum tilt of a collector occurs when the angle of the collector is always the same as the incoming radiation.

Fill in the blank(s) with the word (or words) which most accurately completes the thought.

17. A passive system usually has _____ moving parts and is not the _____ of the people taking this course.

18. A concentrating solar collector best utilizes _____ solar radiation.

19. A chief disadvantage to the use of concentrating collectors involve the expense necessary to _____ on the _____ throughout the day.

20. While a solar air system requires _____ capital costs, _____ energy is required during its life to move the _____ from the collector to storage for use than for a liquid system.

21. Which gives off the greatest quantity of heat: A—a gallon of water cooled from 210° to 188°F, *or* B—a gallon of water cooled from 48° to 18°F? _____

22. Of the absorption refrigeration currently in use, the _____ _____ chillers appear to hold the most promise.

23. Through the use of a solar _____-_____ engine, a dvice such as a heat pump could become a solar related device in both cooling and heating modes.

24. It is essential that the solar heating/solar cooling system provide the maximum possible return for the dollar invested based on savings over the _____, _____, and _____ of conventional heating systems.

25. Boston, Massachusetts receives 5" _____ precipitation per year than Seattle, Washington.

26. The storage of inexpensive _____ fuels make it imperative to design efficient solar heating systems.

27. Beside radiant (solar) energy, three other forms of energy useful to people are: _____, _____, and _____.

28. The electromagnetic spectrum of the sun's rays depicts _____ different types of radiation, but in this course only _____, _____, and _____ are of interest.

29. The instrument used to measure solar energy is called a _____.

30. British Thermal Units per square foot is expressed in abbreviated form as _____.

31. To convert Langleys into British Thermal Units per square foot, multiply Langleys by _____.

32. UV means _____ and is _____ wave length radiation.

33. With the outer space value of solar energy equalling 100 percent, _____ percent is the normal maximum reaching the earth.

34. The cooling capacity of one ton of ice is _____ Btu/h.

35. _____ energy would be intercepted if the collector were to track the sun across the sky.

36. The generally accepted tilt of a heating only collector is latitude plus _____ degrees.

37. Maximum solar intensity occurs at noon when the sun is due _____ in this hemisphere.

38. Atmosphere, vegetation, and physical barriers cause the potentially useful solar energy to _____ from location to location, month to month, day to day, and hour to hour.

In the following multiple choice questions, choose the phrase which most correctly completes the statement and circle the corresponding letter in front of the phrase.

39. The surface temperature of the sun is approximately.

a. 5000°F.
b. 10,000°F.
c. 15,000°F.
d. 30,000°F.

40. Langley/min is the abbreviation for

a. calories per square centimeter.
b. calories per square centimeter per minute.
c. calories per cubic centimeter per Langley minute.

41. The solar constant is equal to

a. 1.940 Langley's/min.
b. 428.7 Btu/(ft^2·h).
c. all of the above.
d. none of the above.

42. Which item is not a component of an all-air solar heating/solar cooling system?

a. Auxiliary furnace
b. Heating/cooling distribution system
c. Solar collector
d. Boiler
e. Cooling unit
f. Thermal storage unit

43. Based on the factors presented in this unit, it is essential that solar heating/solar cooling systems provide the user with

a. comfort and safety.
b. maximum return for dollar invested.
c. a good looking unit.
d. snob appeal.

Be sure your name and address is on your exam before mailing!

PREVIEW OF UNIT TWO

Unit One identified the active solar heating system, and its components, and some of the economic problems related to installing such a system to heat a building. Factors related to solar radiation by direct or diffuse sunlight were considered, as was the heat load demand for understanding the function and placement of components.

Unit Two provides the learner with the nomenclature of solar heating. Many of the products used and the procedures employed are common knowledge to people who understand the electrical, plumbing, and fluid (air or water) handling systems of traditional heating practices. However, there are some components that are unique to solar assisted heating and they will be explained in considerable detail. Keep in mind that solar radiation cannot replace 100% of the annual heat demand, although it may become the primary heat source with traditional heating equipment having an auxiliary function to perform.

The *collector*, which comes in contact with solar radiation, is the topic for Lesson Three. Explanations are given of (1) various type of collectors, (2) how collectors are designed and manufactured, and (3) how collectors transfer the solar radiation into hot air or liquid.

Then, in Lesson Four, the *methods of storing heat* for use during the night or periods of low insolation, are discussed. Some advantages and disadvantages of alternative systems are explained. An introduction to the problems of designing an adequately sized system (to be studied in greater depth in Lesson Six) is provided.

Lesson Five presents the various *control devices* and *specialty items* that are needed to assemble the heating system. Air systems use blowers and dampers, while liquid systems utilize centrifugal pumps and valves to move heat throughout the system. Some of the parts are electrically operated which allows the heating system to operate automatically. Other components (specialty items) are manually controlled and used to either balance or maintain the system.

Learning the names and functions of these components will be helpful when studying the sizing procedures and operation of solar systems in Unit Three.

LESSON THREE
Learning Objectives

Lesson Three is a study of the *solar collector*, commonly referred to as the "heart" of the solar assisted heating system. Regardless of the fluid (air or liquid) which will be moved through the collector, the functions are the same; namely to *collect* solar radiation and *convert* it to heat energy. This lesson deals with the concepts of the function and design, but not specifications, that a manufacturer would use for a given collector. Therefore, after studying this lesson, you should be able to:

1. Explain the differences between flat plate and concentrating collectors.
2. Identify the differences in how air and liquid collectors are designed.
3. Describe the operating principles of various components in the collector.
4. Recognize different absorber plate designs and method of manufacture.

GO TO YOUR TEXTBOOK STUDY LESSON THREE

LESSON THREE
Progress Review

Study Lesson Three in your textbook before you attempt to complete this review. Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

T F 1. Concentrating collectors "funnel" the heat to the absorber.

T F 2. Concentrating collectors pivot during the day.

T F 3. Flat plate collectors can be placced on any side of the roof.

T F 4. Diffuse radiation is unimportant to solar heating.

T F 5. Flat plate collectors are more popular than concentrating collectors.

T F 6. Flat plate collectors are most efficient at noon.

T F 7. Heat energy is the result of solar insolation.

T F 8. Most radiation that strikes the cover is absorbed by the glass.

T F 9. "Long wave conversion" reduces reradiation losses through glass covers.

T F 10. Plastic is a better material than glass for cover plates.

T F 11. The average annual outdoor temperature may determine the number of cover plates needed on a collector.

T F 12. Any kind of glass is as good as another for cover plates.

T F 13. Most efficient collectors have a vacuum between plates.

T F 14. Black paint is not applied to aluminum absorber surfaces.

T F 15. Absorber plates have absorptivities of 60% or less.

T F 16. Liquid collectors are larger than air collectors because of the space needed for piping.

T F 17. Fluid travels upward in all types of liquid collectors.

T F 18. A 30 psi system is classified as a low pressure system.

T F 19. Fluid tubes are always attached to the top surface of the absorber plate.

T F 20. Antifreeze can be used in liquid solar collectors as in automobile radiators to avoid freeze up.

T F 21. Electrolysis is more apt to occur in an air system.

T F 22. Polyurethane foam is the only insulating material for collectors.

T F 23. Since wood rots, collector frames should be made only of metal.

T F 24. Air through a collector array travels from the top of the roof toward the eave.

T F 25. Collectors do not need to be attached flat against the roof.

T F 26. Outdoor temperature can affect collector efficiency.

T F 27. A high temperature at the collector inlet will reduce collector efficiency.

T F 28. Data for collecctor efficiency are collected at or near noon.

Fill in the blanks with the word (or words) which most accurately completes the thought.

29. Two basic types of collectors are _____ and _____.

30. The two transfer systems contain _____ and _____.

31. The parts of a solar collector are:

1. _____ 4. _____

2. _____ 5. _____

3. _____

In the following multiple choice questions, choose the phrase which *most correctly* completes the statement and circle the corresponding letter in front of the phrase.

32. Liquid flow rates through collectors are established near which number of gallons per minute?

    a. .01 gpm/sq ft
    b. .02 gpm/sq ft
    c. .003 gpm/sq ft
    d. .004 gpm/sq ft

33. Flow rates through air collectors are established near which number of cubic feet per minute.

    a. 12 cfm/sq ft
    b. 9 cfm/sq ft
    c. 6 cfm/sq ft
    d. 3 cfm/sq ft

34. The average absorber plate temperature is typically.

    a. 100°F.
    b. 150°F.
    c. 200°F.
    d. 250°F.

35. Heat energy that is visible is above

    a. 200°F.
    b. 500°F.
    c. 800°F.
    d. 1000°F.

36. The "blackbody" refers to the

    a. collector frame.
    b. absorber plate.
    c. insulation.
    d. none of the above.

37. The main *disadvantage* of plastic covers is poor

a. heat transmission.
b. sheet stability.
c. sealing qualities.
d. light transmission.

38. Various manufacturers of air system collectors use _____ to increase conductivity.

a. Insulation
b. Slow speed blowers
c. Polished duct work
d. Fins

39. Sketch the tube patterns in the rectangle representing three collector designs.

Serpentine	Grid, direct	Grid, reverse

Compare your answers with those given in the answer key in the back of this *Study Guide*. If you have any question regarding the correct response to a review item, refer to your textbook for clarification. (See Study Hint No. 9.).

DO NOT RETURN THIS REVIEW QUIZ FOR GRADING

LESSON FOUR
Learning Objectives

Lesson Four is a study of the heat storage unit of a solar assisted heating system. Regardless of the fluid (air or liquid) which will be used as the heat transfer medium, the functions are the same; to store heat for circulation at night or during times of low solar insolation. This lesson deals with the concepts of the function and design but not specifications that a manufacturer or contractor would use for a given heat storage unit. Therefore, after studying this lesson, you should be able to:

1. Identify what material is used for heat transfer mediums.
2. Explain the concepts of sizing a heat storage unit.
3. Solve problems of storage unit sizing.
4. Discuss where storage units can be placed.
5. List factors that affect the advantages and disadvantages of different kinds of heat storage units.
6. Identify advantages and disadvantages of various heat storage practices.
7. Describe the materials used in manufacture and in installation practices for heat storage units.

GO TO YOUR TEXTBOOK STUDY LESSON FOUR

LESSON FOUR
Progress Review

Study Lesson Four in your textbook before you attempt to complete this review. Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

T F 1. All substances can absorb or give off heat.

T F 2. There is approximately six hours difference between typical winter and summer solar exposure.

T F 3. Rock requires less storage space because it is harder.

T F 4. Water and air are the only substances used for heat storage.

T F 5. To retain a comparable amount of heat energy, wax requires a larger heat storage tank than water.

T F 6. Phase change storage systems are not presently used as much as sensible heat storage systems.

T F 7. The best place to locate a heat storage unit is outside the building because it would not take up living space.

T F 8. An attic is an ideal location for a heat storage unit.

T F 9. The only problem with placing a storage unit above ground and outside is its poor appearance.

T F 10. A storage unit can be "too large" for a given system.

T F 11. To warm a space evenly requires a heat storage unit.

T F 12. A reasonable capacity for a liquid storage tank is up to two gallons of water per square foot of collector surface.

T F 13. Heat storage system sizes are calculated according to the coldest possible temperature in a given locality.

T F 14. One way to account for heat from internal sources when calculating daily heat demand is to lower the estimated inside temperature 5°F.

T F 15. A heat storage unit should be adequate for an overnight supply of energy.

T F 16. A heat storage/collector system cannot be economically sized to supply a 100% annual heat load.

T F 17. The liquid storage tank must be heavily insulated.

T F 18. Watertight connections are easy to make for concrete tanks.

T F 19. Almost any fiberglass tank will be satisfactory to store heated water.

T F 20. Several small tanks may be as practical as one large tank for liquid storage.

T F 21. A storage unit that provides 50% of the heat demand is about the maximum size that can be built economically.

Fill in the blanks with the word (or words) which most accurately completes the thought.

22. An alternative to sensible heat storage is a _____ _____ _____.

23. Changing one pound of ice to steam requires _____ Btu's.

24. Attic heat storage could be used for a _____ system when heating _____ _____ _____.

25. Sensible heat storage systems usually use _____ or _____ as the storage material.

26. The size of the storage unit depends on the size of the _____ and the _____.

27. It is inadvisable to use an aluminum collector without protection because of corrosion from _____.

28. The liquid storage unit that is the most expensive to install would probably be made of _____.

29. Pebbles for an air system storage unit are about _____ in diameter.

30. Two types of pebble beds are _____ and _____.

In the following multiple choice questions, choose the phrase which *most correctly* completes the statement and circle the corresponding letter in front of the phrase.

31. The specific heat of water is

a. one degree.
b. one Btu.
c. one Btu per pound.
d. one Btu per pound per degree F rise.

32. Phase change refers to

a. Btu's of insolation.
b. heat of fusion.
c. loss of Btu's.
d. weather changes.

33. An advantage of phase change materials is that they

a. absorb more heat than water.
b. rarely need to be replaced.
c. are inexpensive.
d. insulate easily.

34. A "too small" storage unit

a. increases collector efficiency.
b. reduces collector efficiency.
c. saves money in construction.
d. wastes little or no heat.

35. A reasonable capacity for an air system storage unit is up to _____ cubic feer of rock per square foot of collector surface.

a. One
b. Two
c. Five
d. Ten

36. Thermal stratification in a pebble bed means that

a. the temperature of the bed is constant.
b. there are layers of varying temperature.
c. hot air is heavy.
d. dirt prevents heat absorbing.

37. Three advantages of storing liquids are that

A. _____

B. _____

C. _____

38. Five disadvantages of storing liquids are that

A. _____

B. _____

C. _____

D. _____

E. _____

39. Some advantages of the hot air storage system are that

A. _____

B. _____

C. _____

D. _____

40. Disadvantages of air storage units are that

A. _____

B. _____

C. _____

41. Three materials commonly used to construct liquid storage units are

A. _____

B. _____

C. _____

(Refer to SMACNA Standards for questions 42—44.)

42. The lowest likely temperature for 99% of the total winter hours in Fargo, North Dakota is _____.

43. Cleveland, Ohio is likely to have a minimum temperature of _____ during 97½% of the winter hours.

44. The average winter temperature in Wilmington, North Carolina is _____.

Compare your answers with those given in the answer key in the back of this *Study Guide*. If you have any question regarding the correct response to a review item, refer to your textbook for clarification. (See Study Hint No. 9.).

DO NOT RETURN THIS REVIEW QUIZ FOR GRADING

LESSON FIVE
Learning Objectives

Lesson Five is a study of the various *controls* and *specialty items* of a solar assisted heating system. Blowers and dampers move and divert air in an air system. Centrifugal pumps and valves move and divert liquids in a liquid system. Many of these controls are electrically operated and, for the most part, are made-up of components commonly used by electricians, plumbers, and/or sheet metal workers in the heating-cooling industry. Therefore, after studying this lesson, you should be able to:

1. Discuss the operating principles of a centrifugal circulating pump.
2. Discuss the operating principles of an air circulating blower.
3. Describe how the heat exchanger functions.
4. Identify the various electrical control devices used in solar heating systems.
5. Explain the functions of various hydronic specialty items used in the control of air or liquid in a solar assisted heating system.

GO TO YOUR TEXTBOOK STUDY LESSON FIVE.

LESSON FIVE
Progress Review

Study Lesson Five in your textbook before you attempt to complete this review. Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

T F 1. The word *fluid* as used in these lessons refers to both liquid and air.

T F 2. Pump sizing is not very critical to the solar heating system.

T F 3. Piping creates little or no resistance to liquid flow.

T F 4. Pump capacity decreases as head pressure increases.

T F 5. Pump specifications cannot be established until flow resistance is calculated.

T F 6. Larger pumps are required in the drain down system as compared to a closed loop system of comparable size.

T F 7. Pumps rated at 150 psi are recommended for collector loops.

T F 8. One-speed pumps are as effective as two-speed pumps.

T F 9. Conventional furnace blowers may be installed in solar collector systems using air as the fluid.

T F 10. Static pressure is the type of air pressure measured in automobile tires.

T F 11. In low pressure systems, velocity pressure is most often used as a design standard for moving air.

T F 12. A system's performance cannot be predicted before it becomes operational.

T F 13. A thermostat is an actuator.

T F 14. A solenoid valve is an actuator.

T F 15. An outdoor thermostat is never used in conjunction with the collector (fan) circulation system.

T F 16. A differential thermostat measures temperature in more than one place at the same time.

T F 17. Some thermostats operate because of the difference in expansion of two metals.

T F 18. A bellows/diaphragm sensor must be open to the air to allow liquids to expand.

T F 19. A thermistor functions because of an internal change in electrical resistance.

T F 20. Corrosion will not effect the sensitivity of a thermistor.

T F 21. Thermistors are manufactured in various mountings.

T F 22. A transformer may be designed to either step-up or step-down voltage.

T F 23. Collector loops must be filled manually.

Fill in the blanks with the word (or words) which most accurately completes the thought.

24. The primary circuit connects the _____ to the _____.

25. Pump capacity is given in _____ per _____.

26. To prevent freeze-ups, liquid collector loops are protected by _____ or _____ _____ _____.

27. The most common heat exchanger used between collector and storage is called the _____ and _____.

28. Three types of pressures that apply to air movement are _____, _____ and _____.

29. An air system should operate at a point where the _____ and _____ curves intersect.

30. The two elements of a control system are the _____ and the _____.

31. The first stage of a two-stage thermostat calls for heat from the _____ or _____.

32. The second stage of a two-stage thermostat calls for heat from the _____ _____ _____.

33. Thermistors contain a _____ element.

34. The grease-like material to keep thermistors from losing sensitivity is called a _____ _____ _____.

35. Electrically powered valves are called _____ valves.

36. In an air system, an electrically powered _____ functions like the _____ in a liquid system.

37. A relay is a(n) _____ switch.

38. The specialty item that keeps a closed liquid system operating between specific pressure limits is the _____ _____.

39. Valves that adjust flow rates through the collector array are _____ valves.

40. To reduce corrosion among dissimilar metal piping and components, they are installed by using _____ unions.

41. A manual fill system includes a

A. _____

B. _____

C. _____

42. The fan system curve, or balance point, can be changed by

A. _____

B. _____

C. _____

In the following multiple choice questions, choose the phrase which *most correctly* completes the statement and circle the corresponding letter in front of the phrase.

43. Liquid moving pumps operate with a _____.

a. reciprocating action.
b. syphoning action.
c. pulsating action.
d. centrifugal action.

44. *One* psi of pressure is equal to

a. 0.43 feet of water.
b. 1.00 feet of water.
c. 2.32 feet of water.
d. 3.00 feet of water.

45. The valve that allows fluid movement in only one direction is a

a. check valve.
b. pressure relief valve.
c. balance valve.
d. pressure reducing valve.

46. Complete the drawing for a shell and tube heat exchanger.

Compare your answers with those given in the answer key in the back of this *Study Guide*. If you have any question regarding the correct response to a review item, refer to your textbook for clarification. (See Study Hint No. 9.).

DO NOT RETURN THIS REVIEW QUIZ FOR GRADING

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Score _____
Grade _____
Instructor _____
Date _____

DO NOT WRITE IN THIS SPACE

Fundamentals of Solar Heating
UNIT TWO EXAMINATION

Student's Name _____

Address _____ City _____ State _____ Zip _____

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

T F 1. Although spelled differently, insulation and insolation have the same meaning.

T F 2. The lens of a concentrating collector must remain perpendicular to the rays of the sun.

T F 3. Flat plate collectors are equally efficient any time of the day.

T F 4. Operating temperatures are the same for all types of collectors.

T F 5. A serpentine piping design is used in concentrating collectors.

T F 6. Air spaces between cover plates are sealed from each other.

T F 7. About 95% of the heat that strikes an absorber plate passes into it.

T F 8. Fluid systems refer to either air or liquid being used to transfer heat.

T F 9. Any size blower could be used for the differently designed air collectors.

T F 10. Liquid transfer tubes may only be suspended above or below the absorber plate.

T F 11. "Drain-down" is an alternative to using antifreeze in collector loop.

T F 12. Aluminum is a good material for collector tubing because it can be shaped easily.

T F 13. Metal and fiberglass may be used for collector frames.

T F 14. The reason for needing a storage unit is that solar heat is variable and interruptable.

T F 15. The higher the specific heat of a substance the better it will perform to store heat energy.

T F 16. Water will hold about twice as much as heat as rock for the same volume.

T F 17. Phase change storage can be smaller than water storage for a given Btu capacity.

T F 18. Wax gives off heat when it cools and solidifies.

T F 19. Phase change materials will never be practical.

T F 20. A storage unit cannot be constructed that is considered "too" large.

T F 21. Collector efficiency will be reduced by a storage unit which is too small.

T F 22. A solar heating system must have a heat storage unit.

T F 23. When estimating maximum building heat loss, the average daily temperature is used.

T F 24. Rock will hold heat longer than water.

T F 25. Rocks in a storage unit must be washed periodically if not protected by filters.

T F 26. Standard fiberglass tanks have been proven very servicable even when liquid temperatures approach the boiling point.

T F 27. Glasslined tanks may be the fastest to deteriorate.

T F 28. The basement is the only place that pebble storage can be placed.

T F 29. Blowers are placed in the circuit to take air from storage and move it through the collector.

T F 30. Pressure drop means that fluid flow is being opposed by friction.

T F 31. A "drain down" circuit is always an open loop system.

T F 32. Inhibitors may be added to closed loop circuits.

T F 33. Antifreeze or other special fluid may be added to closed loop circuits.

T F 34. Air systems do not really need to be balanced.

T F 35. Thermistor operation is due to the change in resistance of a wire-wound element.

T F 36. A thermistor needs to be mounted within about 10 feet of its controller.

T F 37. Thermistors are fairly standard in design but there are numerous mounting practices.

T F 38. The component in a liquid solar heating system that is furthest from the ground is a float-type air vent.

T F 39. Fill systems can be either manual or automatic.

Fill in the blank(s) with the word (or words) which most accurately completes the thought.

40. Two types of collectors are the _____ and _____.

41. The alternatives to primer and black paint on an absorber plate are called _____ surfaces.

42. The most effective liquid collector is the _____ _____ _____.

43. Two popular insulating materials for collector frames are _____ and _____ _____.

44. Flow rates for an air system will be about _____ to _____ cfm per sq ft of collector.

45. Flow rates for a liquid system will be about _____ to _____ gpm per sq ft of collector.

46. Two ways to contain heat are with the _____ and _____ _____ storage systems.

47. Selecting a storage medium involves its _____ _____, _____ and _____ of the materials.

48. Two disadvantages of a liquid system caused by temperature change are _____ and _____ points.

49. To move fluids, _____ in a liquid system perform the same function as _____ in the air system.

50. To control fluids, _____ in the liquid system perform the same function as _____ in the air system.

51. Two important pressures in duct systems are _____ pressure and _____ pressure.

52. A control device to measure temperature in two locations is a _____ controller.

53. The first of a two stage thermostat calls for heat from the _____ or _____ and the second activates the _____ _____ _____.

54. The three commonly used heat sensing devices are _____, _____/_____ and _____.

55. To prevent overpressurizing in a liquid system a(n) _____ tank is installed.

56. The use of _____ valves and _____ makes component replacement convenient.

In the following multiple choice questions, choose the phrase which most correctly completes the statement, and circle the corresponding letter in front of the phrase.

57. Transparent covering would be less useful if they could not

a. respond to the heat demand of a building.
b. be removed for cleaning.
c. change temperature rapidly.

58. The preferred cover plate materials is

a. acrylic plastic.
b. low iron glass.
c. high silica glass.
d. not listed above.

59. Collectors installed in Minnesota and Louisiana would

a. be the same.
b. differ in mounted height.
c. have the same tilt angle.
d. require more covers in Minnesota.

60. A "blackbody" refers to the

a. absorber plate.
b. collector frame.
c. black rubber cover gaskets.
d. heat transfer system.

61. Present day selected coatings are

a. extremely durable.
b. highly reliable.
c. relatively inexpensve.
d. about as efficient as paint.

62. Fins are used in air collectors to

a. increase heat transfer.
b. lower internal temperature.
c. restrict air flow.
d. support the absorber plate.

63. A collector rated at 60% efficient indicates the

a. average daily heat transfer.
b. differences between inlet and outlet temperature.
c. heat transferred at noon for given inlet and ambient conditions.
d. amount of sunlight that strikes the collector in a given time.

64. The best estimates of maximum heat contribution that can be economically built in to a solar system is

a. 40%.
b. 60%.
c. 80%.
d. 100%.

65. It is reasonable to build storage units for _____ heat requirement.

a. One day's
b. Two days'
c. Five days'
d. Ten days'
e. Overnight

66. Locations for storage units means using space that is

a. the least valuable.
b. closest to the collector.
c. in the center of the building.
d. outside the structure.

67. Electrolysis in a liquid system

a. increases the efficiency of the collector.
b. inhibits chemical action.
c. reduced the size of the storage unit.
d. causes piping to corrode.

68. Normally, rock beds _____ feet deep will cause a minimum of air pressure drop.

a. Two
b. Four
c. Eight
d. Ten

69. Closed loop and open loop systems differ because of the

a. damper and valve system.
b. heat exchanger.
c. heat transfer medium.
d. design of the storage unit.

70. A thermal compound is needed with some thermistors to

a. adhere them to an absorber.
b. glue them in a well.
c. protect them from air or water.
d. reduce heat loss.

71. An electrically controlled valve is a

a. solenoid valve.
b. relay.
c. thermostat.
d. check valve.

72. An electromagnetic switch is commonly called a

a. solenoid.
b. transformer.
c. relay.
d. controller.

73. Control devices are used for

a. ease of installing the solar heating system.
b. safe and automatic operation.
c. setting manual valves.
d. all of the above purposes.

Be sure your name and address is on your exam before mailing!

PREVIEW OF UNIT THREE

Units One and Two have provided the opportunity for you to study the basic components which are included in a solar heating system. This unit consists of three lessons related to the *sizing* of key components of a typical solar heating system and the *operation* of a total system.

Lesson Six will introduce you to several methods of *selecting the size* of the key components of a typical solar heating system. The techniques presented are based upon research data and provide varying degrees of precision, depending upon their levels of sophistication. You will have the opportunity to consider several important economic factors and learn how they can affect the size of the most economical solar heating system. Also, in this lesson, information will be provided to help you use a computerized system which is available to compute the size of the components required for a solar heating system.

Lesson Seven provides the information necessary to understand how a solar heating system *operates*. The generalizations about operation are presented using a large number of illustrations. In addition, specific information about the important characteristics of a correctly operating solar heating system are presented. With this background, you should be able to evaluate a system to determine if it is functioning correctly.

Lesson Eight provides information about *domestic hot water* (DHW) heating systems. Many solar space heating systems include domestic water heating as a part of the total system. It will be desirable that you understand how this subsystem operates, and know how to select the correct size of each component. Some consumers may be attracted to the installation of just solar domestic water heaters before they make the major investment in a complete solar heating system. The initial cost is much less and the system can be used all year long. A number of solar hot water heating packages are now available which can be installed either in new homes or retrofitted into existing dwellings or commercial buildings. These separate hot water heating systems are given considerable coverage in Lesson Eight.

Taken together, these lessons will enable you to understand how solar heating systems function and how to design efficient solar heating systems. A thorough knowledge of the content of these lessons will enable you to progress to Unit IV where you will study the installation, servicing, and legal aspects of solar heating systems.

LESSON SIX
Learning Objectives

Now that you understand the functions of each of the basic components of a solar heating system, it is time to put them together into a system. In this lesson, you will learn about *sizing the collector.* Once the size of the collector is known, it is possible to compute the *size* of each of the *remaining solar system components.* Your previous experiences with forced air and hydronic heating systems will aid you in your study. As a result of completing this lesson, you should be able to:

1. Identify ten components of a typical solar heating system.
2. Define the term "life-cycle-cost."
3. Use tables to determine the collector size for typical homes.
4. Identify the more important economic factors in sizing solar heating systems.
5. Calculate the size of the heat storage unit required for a typical collector.
6. Calculate the size of the pumps or fans which circulate water and air through the collector.
7. Prepare the input for a computer program which will compute the size of solar system components.

GO TO YOUR TEXTBOOK STUDY LESSON SIX

LESSON SIX
Progress Review

Study Lesson Six in your textbook before you attempt to complete this review. Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

T F 1. The shortage of fossil fuels is one reason why consumers are likely to purchase solar heating systems.

T F 2. When determining the size of solar heating system component, the heat storage unit is sized *first* and all other components are sized in relation to it.

T F 3. For heating only, the optimum angle of a solar collector with respect to the horizon is local latitude plus 15°F.

T F 4. Counterflow design of heat exchangers decreases heat transfer.

T F 5. The higher the approach temperature of the heat exchanger, the higher the efficiency.

T F 6. An air cushion tank provides the normal expansion of the liquid in a liquid solar heating system.

T F 7. The diaphragm in an air cushion tank prevents the air in the tank from mixing with the water.

T F 8. As the costs of natural gas, fuel oil and other forms of fossil fuel energy increase, it becomes *less* economical to install a solar heating system.

T F 9. The additional investment in solar heating equipment will increase the value of a home and is likely to increas the annual tax and insurance bills.

In the following multiple choice questions, choose the phrase which *most correctly* completes the statement and circle the corresponding letter in front of the phrase.

10. Which of the following are considered when life-cycle-costing is applied to the design of a solar heating system.

    a. Initial cost of the system
    b. Expected life of the system
    c. Cost of auxiliary energy
    d. All of the above are considered in life-cycle-costing

11. A collector which is oriented 30° west of south will operate at an efficiency of _____. (Refer to your textbook, Figure 6-10.)

    a. 0.93
    b. 0.98
    c. 0.90
    d. 0.97

12. An air solar system with 400 square feet of collector will require a storage unit containing _____ cubic feet of pebbles.

    a. 200-400
    b. 150-300
    c. 250-600
    d. 450

13. A heat exchanger is installed in a liquid solar heating system to

    a. increase the efficiency of the system.
    b. prevent the collector fluid from boiling.
    c. separate collector loop fluid from the storage loop fluid.
    d. heat domestic hot water.

14. A clearinghouse to obtain complete, up-to-date information about solar systems is

    a. HUD.
    b. National Solar Heating and Cooling Information Center.
    c. ERDA
    d. None of the above

15. The FCHART collector sizing technique is

    a. very simple to use.
    b. a very detailed sizing procedure.
    c. available to customer through some collector manufacturers.
    d. both b and c are correct.

16. A procedure developed at Colorado State University for sizing collectors is based upon

    a. the FCHART system.
    b. rules-of-thumb.
    c. heat exchanger size.
    d. economic analysis.

17. Presently, for most locations the most economically solar heating installation will replace _____ percent of the fossil fuel energy requirement.

    a. 50-70
    b. 40-80
    c. 60-90
    d. 50-55

18. The ERDA computer program which contractors can use to determine optimum collector size and obtain heat loss calculation is known as

    a. FCHART.
    b. Relative Areas Analysis.
    c. Solocost.
    d. Life-cycle-costing.

In the following completion questions, place the correct number, word, or phrase in the blank(s) provided with each question.

19. A home located in Seattle, Washington has a heat loss of 60,000 Btuh for 20°F average outside and 70°F average inside temperature. What size collector will be required if 50% of the energy requirement is to be replaced by solar energy using a liquid system and collector tilt of 53°? Use Table 2-10 in SMACNA Standards. _____ sq ft.

20. One of the simplified procedures outlined in this lesson provided a separate divisor for air and liquid systems. Also, two choices of collector tilt and three choices of percent of solar contribution are given. What is the title of the document where these data can be found?

_____

21. Simplified solar collector sizing procedures do not all produce the same results. Why is this so. A. _____

What must the designer/technician know when applying any of these techniques. B. _____

22. List ten factors which affect the life-cycle-cost of a solar heating system.

_____ _____

_____ _____

_____ _____

_____ _____

_____ _____

Fill in the blanks with the word (or words) which most accurately completes the thought.

23. Referring to the sample Solcost analysis, Figure 6-8, identify the values for the following input parameters:

A. Collector tilt _____ degrees.

B. Solar system fixed initial cost $_____.

C. Property tax rate _____.

24. Referring to the output of the sample Solcost analysis, Figure 6-8, identify the following:

A. Initial solar investment $_____.

B. Collector size _____ square feet.

C. Annual proportion of load provided by solar _____%.

D. Rate of return on net cash flow _____%.

25. The three basic types of heat exchangers are:

A. _____

B. _____

C. _____

26. If a solar system contains 75 gallons of water which enters the system at 55°F and is heated 200°F, what will be the increase in the volume of water?

_____.

Compare your answers with those given in the answer key in the back of this *Study Guide*. If you have any question regarding the correct response to a review, refer to your textbook for clarification. (See Study Hint No. 9.).

DO NOT RETURN THIS REVIEW QUIZ FOR GRADING

LESSON SEVEN
Learning Objectives

In Lesson Six, information was provided about sizing of the various components of a solar heating system. This lesson presents the basics of solar system *operation*. The relationships which must exist between the collector, storage unit, auxiliary furnace, pumps, fans, heat exchangers, and other vital parts of the total system are presented. Finally, the control system which regulates the flow of air and liquid through solar heating systems is discussed. As a result of completing this lesson, you should be able to:

1. Describe the five basic operating modes for air solar heating systems.
2. Determine which components of the systems should be operating and which valves or dampers should be open during each operating mode.
3. Describe the importance of eliminating air leaks in all air solar heating system.
4. Identify the safety devices required on the domestic hot water sub-system.
5. Identify the basic differences between air and hydronic solar heating systems.
6. Describe three different ways heat pumps can be coupled to solar heating systems.

GO TO YOUR TEXTBOOK STUDY LESSON SEVEN

LESSON SEVEN
Progress Review

Study Lesson Seven in your textbook before you attempt to complete this review. Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

T F 1. When heating directly from the collectors of an all air system, the heated air normally passes through the storage unit before entering the space to be heated.

T F 2. Heating domestic water is possible by adding a fin tube heat exchanger in the air stream leaving the collector.

T F 3. A T/P valve is installed at the pre-heated domestic water tank to prevent overheating of this water.

T F 4. Ducts with insulation value of R-4 should be installed to reduce heat loss in an all air system.

T F 5. A bypass duct is always required in an all-air solar system.

T F 6. When storing heat with a hydronic solar heating system the storage pump is off.

T F 7. When heat is being stored in a closed loop hydronic solar heating system the collector fluid flows directly to the storage unit.

T F 8. The purpose of the purge cycle is to drain the fluid from the collector.

T F 9. The simplest installation of a heat pump in a solar heating system is to use the heat pump as an auxiliary heat source.

T F 10. A heat pump can be installed so it will draw heat from the solar storage unit.

T F 11. The collector pump will short-cycle if the "on" and "off" points on the differential thermostat are too close.

In the following multiple choice questions, choose the phrase which *most correctly* completes the statement and circle the corresponding letter in front of the phrase.

12. One way to prevent scalding water from entering the domestic hot water line, is to install a

    a. pressure/temperature relief valve.
    b. drop line.
    c. thermostatic mixing valve.
    d. air cushion tank.

13. A well designed all air solar system will have a pressure drop of approximately 0.3 inches of water in the

    a. collector.
    b. storage unit.
    c. duct system.
    d. both a and b are correct.

14. The collector loop of a hydronic solar system contains

    a. collector.
    b. heat exchanger.
    c. pump.
    d. all of the above.

15. If a heat pump is used for auxiliary heat, the "solar" water coil is installed upstream from the refrigerant coil to

    a. avoid higher head pressures on the compressor.
    b. make installation easier.
    c. to increase the heat output from the heat pump.
    d. all of the above are correct.

In the following completion questions place the correct number word, or phrase in the blank(s) provided with each question.

16. List the five basic modes of operation possible with all air solar systems:

    A. _____.

    B. _____.

    C. _____.

    D. _____.

    E. _____.

17. The flow path of air through the storage unit when heat is being stored is _____ the air flow when heating from storage.

18. Why is air leakage more of a problem in all-air solar heating systems than in conventional forced air heating systems?

    A. _____.

    B. _____.

    C. _____.

    D. _____.

19. To achieve quiet operation, all blowers should be _____ driven.

20. Dampers on all air systems be fitted with _____ _____ seals for positive shut-off and smooth operation.

21. Refer to Figure 7-14 in your text and determine what mode of operation is in effect when the following conditions exist:

	OPERATING MODE	STORAGE PUMP	COLLECTOR PUMP	AUXILIARY HEATER	LOAD PUMP	FAN
A.	_____	On	On	Off	Off	Off
B.	_____	Off	Off	Off	On	On
C.	_____	On	On	Off	On	On
D.	_____	Off	Off	On	Off	On

Compare your answers with those given in the answer key in the back of this *Study Guide*. If you have any question regarding the correct response to a review item, refer to your textbook for clarification. (See Study Hint No. 9.)

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LESSON EIGHT
Learning Objectives

Solar heating of *domestic hot water* (DHW) is growing rapidly in the United States. Many solar domestic hot water heating systems are available for new installations as well as retrofitting into existing homes. This lesson introduces the basic types of systems available, considers each of the principal components of the system individually, discusses the operation of these systems, presents information about sizing the components, and deals with the principal economic question which must be answered before deciding to purchase a solar domestic water heating system. As a result of completing this lesson, you should be able to:

1. Describe the three basic types of solar domestic water heating systems and identify the basic components of each.

2. Understand and be able to discuss the advantages and disadvantages of air versus liquid systems.

3. Describe the operating cycles of the three basic systems for heating domestic water.

4. Compute the size of the collector required for typical residential installation.

5. Analyze the economic considerations which are important to the decision to purchase a solar domestic water heating system.

GO TO YOUR TEXTBOOK STUDY LESSON EIGHT

LESSON EIGHT
Progress Review

Study Lesson Eight in your textbook before you attempt to complete this review. Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

T F 1. Solar domestic hot water heating is presently more economical than whole house space heating.

T F 2. The direct heating/thermosiphon system is well suited to northern climate.

T F 3. Direct water heating systems require drains to be installed in the collector loop to prevent freeze damage.

T F 4. Indirect solar water heating collector systems have been developed to overcome the freezing problems of direct heating systems.

T F 5. Indirect water heating systems can use either air or liquid (hydronic) collectors.

T F 6. Double wall heat exchangers are generally required in liquid solar water heating systems.

In the following multiple choice questions, choose the phrase which most correctly completes the statement and circle the corresponding letter in front of the phrase.

7. The simplest form of the solar domestic water heating system is the

   a. indirect heating/thermosiphon.
   b. direct heating/thermosiphon.
   c. direct heating/pump circulating.
   d. indirect heating/pump circulating.

8. In a direct heating/thermosiphon system the water storage tank must be

   a. located 1 to 2 feet above the collector.
   b. located 1 to 2 feet below the collector.
   c. made of fiberglass.
   d. larger than in any of the other systems.

9. Excessive hot water is prevented from entering the domestic hot water service line by installing a

   a. check valve.
   b. P/T valve.
   c. an automatic drain valve.
   d. thermostatically controlled mixing valve.

10. To prevent excessive build-up or hot water or steam in the storage tank a

   a. check valve is installed.
   b. P/T valve is installed.
   c. an automatic drain valve is installed.
   d. thermostatically controlled mixing valve is installed.

11. Among the major advantage(s) of using air rather than water as a transfer medium is/are:

   a. freedom from freezing and boiling.
   b. no risk loosing expensive fluid in collector loop.
   c. no risk of damaging leaks.
   d. all of the above.

12. The major disadvantage(s) of using air rather than water as a transfer medium is/are:

   a. larger collector required.
   b. larger piping required to connect components.
   c. more energy required to circulate air.
   d. all of the above.

Fill in the blanks with the word (or words) which most accurately completes the thought.

13. Describe two disadvantages of direct heating/thermosiphon solar domestic water heating systems.

   A. _____.

   B. _____.

14. A _____ valve is installed in the collect loop of a solar domestic water heating system to release excessive pressure and allow any steam which may be created to escape.

15. Label each of the lettered components of the direct heating/pump circulating system shown at the right.

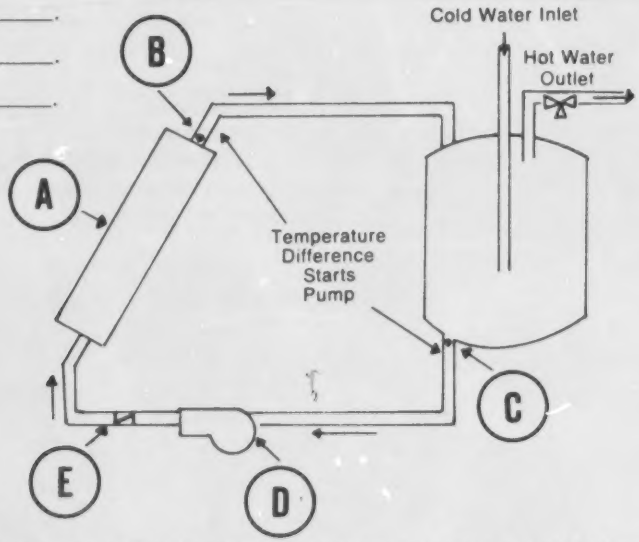
A. _____.

B. _____.

C. _____.

D. _____.

E. _____.



16. Using Table 8-1, calculate the daily Btu requirement for a family of four living in a three bedroom home which is supplied with service water at a temperature of 45°F. Assume that the desired temperature of the heated water is 155°F. _____.

Compare your answers with those given in the answer key in the back of this *Study Guide*. If you have any question regarding the correct response to a review item, refer to your textbook for clarification. (See Study Hint No. 9.)

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Instructor _____

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DO NOT WRITE IN THIS SPACE

Fundamentals of Solar Heating
UNIT THREE EXAMINATION

Student's Name _____

Address _____ City _____ State _____ Zip _____

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

T F 1. Solar heating equipment manufacturers may use their own sizing procedures.

T F 2. There is only one accurate way to determine the collector size for either the air or liquid system.

T F 3. A fixed collector array will satisfy the same percentage of the heat demand consistantly in all buildings in a given location.

T F 4. Doubling the size of the collector means doubling the heat output.

T F 5. Counterflow between hot and cold fluids improves heat transfer.

T F 6. Modern expansion tanks may be open to the atmosphere.

T F 7. Typically there are three blowers in an air system.

T F 8. Minimizing blower horsepower and air leaks are important considerations in an air system.

T F 9. Properly designed, the auxiliary system operates more hours per day than the collector loop.

T F 10. Listed duct coil Btu ratings may be reduced by non-uniform air velocity over coil.

T F 11. Sensors are placed at the inlet and outlet of the collectors for system operating purposes.

T F 12. In a closed loop hydronic system, more than one pump may operate at a given time.

T F 13. A heat pump can provide both heating in winter and cooling in summer.

T F 14. Because of excessive cost, DHW systems should *not* be installed alone.

T F 15. The thermosiphon system requires a low speed circulating pump.

T F 16. The thermosiphon system would be simple to operate in Florida.

T F 17. Safety valves are required for thermosiphon DHW systems.

T F 18. When heating DHW, the auxiliary system should be used *only* when solar insolation is insufficient.

T F 19. A relief valve to relieve pressure must be plumbed to an open drain.

T F 20. Air system collectors are larger than liquid system collectors when used for DHW of similar capacity.

T F 21. Almost any type of heat exchanger meets the code for DHW systems.

T F 22. By designing a 60% January hot water demand system, it would accommodate almost 100% of the June demand.

T F 23. There are numerous styles of heat exchangers.

Fill in the blanks with the word (or words) which most accurately completes the thought.

24. As a rule of thumb, the collector area required for space heating is equal to _____ the floor space being heated.

25. The FCHART is a `able to determine _____ _____.

26. To accommodate the expansion of water in a closed loop system, _____ _____ _____ tank is installed.

27. PSIG means _____ _____ _____ _____ _____.

28. When heating from storage, the auxiliary system operates only during _____ stage demand of thermostat.

29. Collector efficiency at times of both high and low insolation may be increased by _____ _____ pumps.

30. A reasonable rate of consumption for DHW is _____ gallons per person per day.

31. List the four essential solar system operating modes.

A. _____.

B. _____.

C. _____.

D. _____.

In the following multiple choice questions, choose the phrase which most correctly completes the statement and circle the corresponding letter in front of the phrase.

32. Typical collector efficiency for DHW is probably

a. 10%.
b. 40%.
c. 70%.
d. 100%.

33. When justifying solar installation for economic purposes, the expense most applicable is the

    a. cost of equipment.
    b. cost of labor.
    c. tax break.
    d. life-cycle cost.

34. Optimum tilt angle for solar heating is latitude plus _____ degrees.

    a. 0
    b. 5
    c. 15
    d. 30

35. Optimum tilt angle for DHW is latitude plus _____ degrees.

    a. 0
    b. 5
    c. 15
    d. 30

36. The desired heat exchange approach temperature is

    a. 0
    b. 10
    c. 20
    d. 30

37. Air cushion tanks can be located a few feet

    a. above the collector.
    b. below the collectors.
    c. above the storage unit.
    d. below the storage unit.

38. To prevent water from flashing to steam at the top of a collector, the

    a. static pressure is increased.
    b. static pressure is decreased.
    c. air vent is closed.
    d. balance valves are adjusted.

39. A diaphram style air cushion tank allows for using _____ cushion tanks.

a. Larger
b. Smaller

40. When ethylene glycol is used at a 50% concentration, expansion tanks must be _____ in size.

a. Increased
b. Reduced

41. In the summer, when there is no immediate heat demand for DHW, the air system collector loop.

a. continues to circulate hot air.
b. continues to heat the water.
c. exhausts to the atmosphere.
d. overheats the collector.

42. The component that prevents scalding DHW water temperatures is

a. a heat controller.
b. a mixing valve.
c. an air vent.
d. the dual thermostat.

43. Total pressure loss in an air system may be as high as _____ inch of water.

a. 0.3
b. 0.6
c. 0.9
d. 1.0

44. A common air velocity inducts would be _____ feet per minute.

a. 200
b. 400
c. 800
d. 1200

45. The *least* effective low temperature liquid space heat system with solar assistance is the

    a. liquid to air unit.
    b. hdronic baseboard unit.
    c. heat exchanger unit.
    d. low pressure storage unit.

46. When the collector loop cannot supply enough heat directly the

    a. house gets cold.
    b. storage unit heat is used.
    c. auxiliary heat is used.
    d. circulating pumps operate in reverse.

47. A disadvantage of a heat pump as auxiliary heat may be

    a. ineffective movement of the liquid.
    b. use of unstable liquids.
    c. large space that the pump occupies.
    d. cost of electricity required to operate them.

48. Differential thermostats are typically set to start when the temperature difference between collector and storage is about _____.

    a. 3°F
    b. 6°F
    c. 10°F
    d. 20°F

49. The simplest DHW system to operate is the _____ system.

    a. thermosiphon
    b. liquid circulating
    c. air circulating
    d. combination of b and c

50. The most difficult DHW system to integrate into the structure is the _____ system.

a. thermosiphon
b. liquid circulating
c. air circulating
d. combination of b and c

51. Check valves prevent

a. overheating the collector.
b. short cycling.
c. reverse circulation.
d. system drain-down.

52. In the direct heating/pump circulating DHW system, _____ prevents freezing.

a. antifreeze
b. reverse circulation
c. high speed pump action
d. a drain-down valve

53. The first concern in sizing is

a. heat storage unit.
b. air handler.
c. collector.
d. heat exchanger.

54. In the indirect heating/pump circulation DHW system, _____ prevents freezing.

a. antifreeze or special fluid
b. reverse circulation
c. high speed pump action
d. a drain-down valve

Be sure your name and address are on your exam before mailing!

PREVIEW OF UNIT FOUR

Unit Four provides the learner with information about *installing* and *servicing* solar assisted heating systems, in addition to discussing some of the areas of *legal* concerns for new construction or existing structures being retrofitted. In preparation for this unit, you have studied the components of the open and closed loop systems, how they are sized, and how they operate.

Lesson Nine discusses the installation of collectors, heat storage units, control devices, and specialty items. Special emphasis is placed on the scheduling of events in the sequence of activities in constructing the building. SMACNA and other organizations have established standards and guidelines for many of the installation practices used in the construction industry that apply to solar heating.

Specifications and drawings for the structure provide the manufacturer's name and model for different components in the solar heating system, as well as for the rest of the structure. Manufacturers of larger pieces of the heating equipment provide specific data for mounting and adjusting procedures for their products. The installer needs this information as do the designer and builder of the home or business being constructed.

Lesson Ten identifies three kinds of servicing procedures for solar heating systems: first, is installation start-up; second, is periodic maintenance; and, third, is troubleshooting or emergency repairs. Discussions are directed toward the installer, servicer, and consumer or owner of the property.

Lesson Eleven deals with legal matters that are designed to protesct people and property. The health and safety of people and property are extremely important to designers, installers, and consumers of solar heating systems. Concern for property deals with such topics as right to light, zoning, building codes, construction practices, and other real estate management problems.

LESSON NINE
Learning Objectives

Lesson Nine provides the learner with information about the sequence of events for installing liquid and air solar assisted heating equipment as well as domestic hot water (DHW). These installations are discussed first for new construction and then for retrofitting an existing structure. Topics are presented in the order that they would normally occur in construction scheduling. In addition, the practice of insulating ducts and pipes at the proper time is also presented. Therefore, after studying this lesson, you should be able to:

1. Explain architectural problems related to installing solar heating systems.
2. Schedule and install collector arrays.
3. Schedule and install heat storage units.
4. Schedule and install controls and specialty items.
5. Schedule and install domestic hot water (DHW) systems.
6. Schedule and install insulation.

GO TO YOUR TEXTBOOK STUDY LESSON NINE

LESSON NINE
Progress Review

Study Lesson Nine in your textbook before you attempt to complete this review. Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

T F 1. Liquid heat storage units can be put in place any time during construction.

T F 2. The bottom of the storage tank should be on the floor for stability.

T F 3. Collectors must be joined to each other as tightly as possible.

T F 4. Some collectors should be covered after installation so they will not overheat internally before being placed in operation.

T F 5. The reverse return array assembly is the easiest to balance.

T F 6. Centrifugal pumps must have positive water pressure on the intake side.

T F 7. In an open loop system, the heat storage unit must contain antifreeze.

T F 8. The open loop system is frequently installed in locations where subfreezing temperatures are rare.

T F 9. In long pipe runs, expansion must be considered.

T F 10. Short lengths of rubber hose can perform the same function as dielectric unions.

T F 11. Rough-in electrical installation includes locating sensors and thermostats.

T F 12. Rock must be uniform in size for the pebble-bed storage unit.

T F 13. Sensors are installed in air system collectors after they are solidly mounted on the roof.

T F 14. Ducts for air system collector loops are installed in the same manner as conventional furnace ductwork.

T F 15. Ductwork may be insulated inside as well as outside.

T F 16. Ductwork to blower connections are made with flexible connectors.

T F 17. Air filters are more critical in the liquid collector circuit than the air system circuit.

T F 18. An electronic air cleaner should not be placed at the inlet to the auxiliary heat source because of high velocity air movement.

T F 19. The air handling module contains most of the electrical controls for its operation.

T F 20. Insulation for the outside surfaces of air system ductwork is added after leak testing is done.

T F 21. Humidifiers can not be used with all air solar systems.

T F 22. Relief valves in DHW system are typically rated at 50 psi just as the collectors.

T F 23. The setting for the mixing valve for liquid DHW is 140°F.

T F 24. A collector could be mounted flat on a 4/12 pitch roof but maximum output would be reduced.

T F 25. Pebble-bed storage units can be placed outside the structure.

T F 26. Liquid storage tanks can never be placed outside the structure.

Fill in the blanks with the word (or words) which most accurately completes the thought.

27. The practice of installing a solar heating system in an existing structure is called _____.

28. Footings for liquid heat storage tanks are engineered according to the weight of the _____ and _____.

29. The preferred collector mounting practice is to mount it to a roof constructed at the proper _____ _____ _____.

30. Space must be allowed at the top of collector array for the installation of the _____ _____.

31. Piping made of _____ _____ or _____ _____ are used for liquid collector loops.

32. Expansion tanks are sized according to the _____ and the _____ _____in the system.

33. Aluminum metal strips in a _____ erode away and reduce chemical attack in the rest of the liquid collector loop.

34. The basic steps involved in roofing a solar heated building are

A. _____

B. _____

C. _____

35. Three possible liquid collector to collector assembly procedures are

A. _____

B. _____

C. _____

36. Three possible liquid collector array circuits are

A. _____

B. _____

C. _____

37. An air handling system module may contain

A. _____

B. _____

C. _____

D. _____

38. Materials to insulate a solar heating system should have

A. _____

B. _____

C. _____

D. _____

E. _____

F. _____

In the following multiple choice questions, choose the phrase which most correctly completes the statement and circle the corresponding letter in front of the phrase.

39. Tank installation is done before the

a. basement floor is poured.
b. floor joists are placed.
c. subfloor is nailed down.
d. basement floor is installed.

40. For drainage purposes a minimum pitch in piping is _____ per 10 feet.

a. ¼"
b. ½"
c. 1"
d. 2"

41. An air handling module directs airflow for

a. space heating from the collector.
b. space heating from the storage unit.
c. space heating from the auxiliary heat unit.
d. all of the above.

42. Four gallons of liquid per minute flowing through a ½" pipe at 422fps will have a pressure drop of _____psi/100 ft. (Refer to textbook.)

a. 4.22
b. 6.36
c. 6.60
d. 7.42

43. A 1" pipe at 5.57 fps with a pressure drop of 6.36 psi will flow at _____ gpm.

a. 4
b. 8
c. 15
d. 25

Compare your answers with those given in the answer key in the back of this *Study Guide*. If you have any question regarding the correct response to a review item, refer to your textbook for clarification. (See Study Hint No. 9.)

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LESSON TEN
Learning Objectives

Lesson Ten deals with the topic of servicing solar assisted heating systems. The information relates to servicing the system after equipment has been installed. Prior to this time, there may have been some testing and inspecting done during rough-in activities.

The system must first be serviced for start-up. This means that the system must be filled with water (or air), and controls must be checked to see that they operate the system properly. A check list must be completed and given to the owner that provides the properly balanced system's operating conditions. Checklists are prepared for both the liquid and the air systems as well as DHW.

Instructions are also provided for period maintenance. This is information that should be given to the owner.

There is also a need to understand troubleshooting practices for use in an emergency.

Therefore, after studying this lesson, you should be able to:

1. Discuss the general information necessary for start-up.
2. Perform the operations necessary to start-up a liquid system.
3. Perform the operations necessary to start-up an air system.
4. Identify the periodic maintenance procedures for various components of the solar heating system.
5. Explain the troubleshooting procedures for a system that needs emergency servicing.
6. Discuss maintenance problems that are common among solar heating systems.
7. Describe the purpose and extent of warranties.

GO TO YOUR TEXTBOOK STUDY LESSON TEN

LESSON TEN
Progress Review

Complete this review. Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

T F 1. Safe procedures are important in servicing a solar heating system.

T F 2. Collectors may reach temperatures well above the boiling point of water.

T F 3. A good designer will prescribe the precise location for every element of the system.

T F 4. Start-up begins after components are in place, leak tests are completed and electrical controls are installed.

T F 5. It is almost impossible to totally purge air from a liquid system at start-up.

T F 6. Capping drain valves after start-up will prevent accidental drain down.

T F 7. Controllers operate as a result of the electrical current flow through the sensors.

T F 8. The system installer should complete a checklist and give it to the customer.

T F 9. Instruments to balance a solar heating system must be calibrated regularly.

T F 10. Absorber panels are anodized and not subject to chipping or peeling.

T F 11. Duct leaks should be located before building is closed in.

T F 12. Sensors typically cannot be repaired in the field.

T F 13. Most electronic controls will have to be adjusted at the time of start-up.

T F 14. Some heat transfer fluids may deteriorate seals and gaskets.

T F 15. Manufacturers generally guarantee the efficiency of their solar equipment.

T F 16. Manufacturers are likely to guarantee solar heating systems if they manufacture all components and certify to the training of installers.

T F 17. Poor packaging and shipping practices are a major cause of system malfunction.

T F 18. There are more problems with low pressure systems than there are with high pressure systems.

Fill in the blanks with the word (or words) which most accurately completes the thought.

19. The two most prevalent servicing hazards are _____ and _____.

20. Low voltage circuits of _____ volts is used for _____, _____ and _____.

21. To insure that all air is removed from a liquid system at start-up, the serviceman must _____ each day for several days of operation.

22. Equalizing the temperature at the top of a liquid collector array is done by an adjustment of a _____ at the top of the collector.

23. Sensor accuracy is affected by a _____ or lack of _____.

24. Organized _____ _____ are essential to a systematic approach to balancing.

25. Clogged collector weep holes cause a _____ _____.

26. Depositing a film on the inside of the collector from vaporzing materials is called _____.

27. A limited warranty is free of defects in _____ and _____.

28. Glycol in a collector loop should be about _____% concentration.

29. Aluminum collectors will corrode rapidly unless a _____ is installed.

30. Fiberglass tanks must be rated for at least _____°F.

31. Start-up involves
    A. _____
    B. _____
    C. _____

32. Periodic maintenance involves checking:
    A. _____
    B. _____
    C. _____
    D. _____
    E. _____
    F. _____

33. An air handler contains:
    A. _____
    B. _____
    C. _____
    D. _____
    E. _____

34. If a motor fails to operate, the electronic control should be replaced only after completing four troubleshooting activities which are to

A. _____

B. _____

C. _____

D. _____

35. The basic approach to troubleshooting is to

A. _____

B. _____

C. _____

D. _____

36. Four main categories of system failure are

A. _____

B. _____

C. _____

D. _____

37. The following list is typical of the tools needed to balance an air system.

A. _____

B. _____

C. _____

D. _____

E. _____

F. _____

G. _____

In the following multiple choice questions, choose the phrase which most correctly completes the statement and circle the corresponding letter in front of the phrase.

38. "Out of adjustment" complaints result when the

    a. heating capacity seems to be decreasing.
    b. heating is uneven and drafty.
    c. operating cost is increasing.
    d. noise level is rising.
    e. all of the above.

39. Of the following, which does *not* affect the efficiency of a collector?

    a. Condensation
    b. Leakage
    c. Dust
    d. Cracked rubber mounts

40. The periodic maintenance of an air handler requires

    a. damper adjustment.
    b. testing concentration of antifreeze.
    c. adjusting balance dampers.
    d. lubrication.

Compare your answers with those given in the answer key in the back of this *Study Guide*. If you have any question regarding the correct response to a review item, refer to your textbook for clarification. (See Study Hint No. 9.)

DO NOT RETURN THIS REVIEW QUIZ FOR GRADING

LESSON ELEVEN
Learning Objectives

The *legal* responsibilities for those who design, engineer, install, and use solar assisted heating systems are two-fold. There is responsibility for (1) the health and safety of people who may be in contact with the system, and (2) the protection of the property in order to construct and maintain an efficient and effective heating system.

People must be informed about possible toxic or allergic reactions that result from contact with materials used in the system. There is also the possibility of electrical shock or burns.

Property must be protected by enforcing building codes and licensing practices for installers and servicing personnel. There are also problems related to real estate that deal with appraisal practices, incentives to invest in solar heating, insurance, and warranties of components in the system.

Therefore, after studying this lesson, you should be able to:

1. Describe the hazarads of a solar heating system harmful to people and property.
2. Identify and explain the problems relating to right to light and freedom from glare.
3. Discuss building codes and zoning requirements.
4. Identify minimum quality standards and installation requirements for solar systems.
5. Describe problems related to property appraisals.
6. Analyze problems related to incentives to invest in a solar system.
7. Identify problems relating to insurance and solar systems.
8. Describe problems relating to warranties and solar systems.

GO TO YOUR TEXTBOOK STUDY LESSON ELEVEN

LESSON ELEVEN
Progress Review

Study Lesson Eleven in your textbook before you attempt to complete this review. Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

T F 1. There is attention given to the health and safety of people related to solar heating utilization.

T F 2. A solar home owner can do nothing if a neighbor's tree grows and shades the collector.

T F 3. It is extremely difficult to find consistent building codes for solar heated buildings.

T F 4. The *Uniform Solar Energy Code* has been found unacceptable for solar heating standards and guidelines.

T F 5. Cross connection refers to hooking potable water with sewer connections.

T F 6. Due to the lack of local codes, inspectors show little concern for solar heating equipment.

T F 7. Changing components may be simpler than changing codes if controversy arises.

T F 8. Because of the urgency to experiment with solar heating, there aren't any jurisdictional labor problems.

T F 9. A solar heating system may be considered a liability by some appraisal practices.

T F 10. Insurance companies are very reluctant to underwrite solar heated buildings.

T F 11. The Federal Trade Commission is the agency that regulates warranties.

T F 12. A full warranty may only relate to a part of a product.

T F 13. A full warranty states that there cannot be a time limit to the duration of the guarantee.

T F 14. Pro-rating is generally associated with limited warranties.

T F 15. A limited warranty protects only the original purchaser.

T F 16. Implied warranties are explicit in identifying the function of a product.

T F 17. Warranties are to be prominantly displayed on the product or packaging.

Fill in the blanks with the word (or words) which most accurately completes the thought.

18. Several aspects of health and safety in owning solar heating equipment relate to _____ and _____ problems.

19. Problems of "Right to Light" arises from _____ and _____ shading.

20. If a collector creates glare, the property owner may be required to _____ _____ _____.

21. Proper placement and purpose for building on a lot in a given location is related to _____.

22. Incentives to install a solar systsem may be encouraged by legislation could be considered _____ or _____.

23. Compensatory regulations would deal with _____ and _____, such as _____, _____ and _____.

24. Warranties are classified as either _____, _____, or _____.

25. Problems with building codes relate to the

A. _____

B. _____

C. _____

D. _____

26. When dealing with solar heating systems, an appraiser may choose to

A. _____

B. _____

C. _____

27. Regulatory legislation includes

A. _____

B. _____

C. _____

D. _____

In the following multiple choice questions, choose the phrase which most correctly completes the statement and circle the corresponding letter in front of the phrase.

28. A full warranty must include

a. repairs at no cost and done in reasonable time.
b. cover only original purchase.
c. if not repairable replace or refund money.
d. all of the above.

29. Which of the following considerations must be dealt with when determining placement of solar collectors.

a. Freedom from glare
b. Right to light
c. Building codes
d. All of the above
d. None of the above

Compare your answers with those given in the answer key in the back of this *Study Guide*. If you have any question regarding the correct response to a review item, refer to your textbook for clarification. (See Study Hint No. 9.)

DO NOT RETURN THIS REVIEW QUIZ FOR GRADING

Remove this exam from your Study Guide

Score _____

Grade _____

Instructor _____

Date _____

DO NOT WRITE IN THIS SPACE

Fundamentals of Solar Heating
UNIT FOUR EXAMINATION

Student's Name _____

Address _____ City _____ State _____ Zip _____

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

T F 1. It is not necessary to install a 100% auxiliary heat system.

T F 2. Retrofit is the practice of installing a solar heating system in an existing building.

T F 3. Heat storage units can be installed any place on a concrete slab basement floor.

T F 4. Glass lined steel tanks are virtually trouble-free.

T F 5. Since collectors are light weight, little truss and rafter reinforcement is needed.

T F 6. The fewer number of pipe fittings used, the lower the pressure drop.

T F 7. Roofing is applied after direct mounted collectors have been installed.

T F 8. Liquid collectors are usually placed with the outlet and inlet connectors at the top and bottom respectively.

T F 9. Collector panels must be thoroughly inspected before being hoisted into place.

T F 10. Expansion and contraction is not a problem of securely mounted collector panels.

T F 11. Solar systems may require larger expansion tanks than conventional water filled hydronic systems.

T F 12. If rubber hose is used in a liquid system it must withstand 150 psi.

T F 13. A getter column reduces corrosion.

T F 14. Sensors should be in place before rough-in electrical work is done.

T F 15. Leak testing a system is done before drywall is hung.

T F 16. Control panels can easily be located in cabinets or closets.

T F 17. Rough-in electrical work precedes weatherization.

T F 18. A pebble-bed does not require as much insulation as a liquid storage tank.

T F 19. When planning a collector array, it's good practice to leave room for adding more collectors in the future.

T F 20. Air filters are less important in an all-air solar system.

T F 21. Tight fitting dampers are crucial to the performance of all air systems.

T F 22. Wood frame construction cannot be used to erect a pebble-bed storage container.

T F 23. Standard sheet metal installation practices are not appropriate for solar duct work.

T F 24. Ducts may be insulated internally or externally.

T F 25. There is no danger of freeze up in an air collector solar domestic water heater.

T F 26. A closed loop DHW system may use 30 psi rated relief valve in collector loop.

T F 27. All DHW systems use 125 psi rated temperature/pressure relief valves.

T F 28. The area below a garage floor can be used for heat storage units.

T F 29. The more that fiberglass insulation is compressed, the more effective it becomes.

T F 30. Under certain conditions collectors can reach temperatures of 300°F.

T F 31. Some air remains in suspension in a liquid system and cannot be vented until the fluid is heated.

T F 32. The installer must design a different kind of sensor mount to be used in each specific location.

T F 33. Shorting out a sensor will simulate an extremely cold condition.

T F 34. Disconnecting the collector sensor from the control simulates an extremely cold condition.

T F 35. Overloading is a common cause of failure in electrical equipment.

T F 36. Outgassing is the depositing of an oily or powdery film on a cover plate.

T F 37. A limited warranty means the product is free from defects in material and craftsmanship.

T F 38. Solar heating systems conform easily to the Home Owners Warranty plan available when a home is sold.

T F 39. All equipment should be labeled if it is hazardous.

T F 40. Plugged weep holes are a problem within ductwork.

T F 41. Solar heating systems are hazard-free.

T F 42. Very few communities have legislated special coding for solar heated building construction.

T F 43. Some states have passed "Right to Light" laws.

T F 44. Some standards have been developed for solar heating systems by the federal government.

T F 45. Building inspectors should be contacted before construction begins.

T F 46. Local jurisdictional problems may exist when solar systems construction contracts are negotiated.

T F 47. All money lending agencies consider solar heating systems to be an asset to the property.

T F 48. Collectors are considered high risk factors for comprehensive insurance.

T F 49. An installer should give all warranties and product information to the owner after the system is in operation.

Fill in the blanks with the word (or words) which most accurately completes the thought.

50. Footings must be sufficient to place liquid storage tanks _____ above the basement floor.

51. Rough-in electrical work includes running electrical service to the _____ and wire to the _____.

52. Rock storage units are generally constructed of _____, _____, or _____.

53. Rough-in ductwork begins _____ _____ _____.

54. Electrical service of _____V and _____V are required at the control panel but this is transformed to _____V for most control circuits.

55. Liquid DHW circuits are classified as _____ loop or _____ systems.

56. Minimum thickness of insulation for storage tanks should be _____ inches, and for pipes and ducts, it should be _____ inches.

57. Start-up of a liquid system involves _____ the system, testing _____ and measuring _____.

58. Anemometers, tachometers, and manometers would be needed to balance a (an) _____ solar heating system.

59. A proportional control is needed for _____ _____ fans and pumps.

60. Right to light problems arise from interference from _____ and _____.

61. Some examples of tax breaks as incentives to invest in solar heating are _____, _____, and _____ taxes.

In the following multiple choice questions, choose the phrase which most correctly completes the statement and circle the corresponding letter in front of the phrase.

62. The roof pitch for direct mounted heating only collectors on building at 30° latitude would be

a. 6/12 or 26½°.
b. 7/12 or 30°.
c. 12/12 or 45°.
d. 4/12 or 18½°.

63. Collector sensors should be installed

a. before inspection.
b. before hoisting the collector to the roof.
c. after hoisting the collector to the roof.
d. when installing electrical circuits.

64. To drain properly, horizontal piping must have _____ pitch for each 10 feet of run.

a. ¼ inch
b. ½ inch
c. 1 inch
d. 2 inches

65. Insulation requirements are engineered to

a. counteract heat loss.
b. fill the walls.
c. cover the foundation.
d. cover the ceiling joists.

66. Much of the responsibility for equipment placement is delegated to the

a. architect.
b. designer.
c. installer.
d. owner.

67. If a system is *not* performing properly major changes to the system should be made only after

a. redesigning the system.
b. heat losses are reduced.
c. adding tubing to the collector.
d. using larger rocks in the pebble-bed.

68. To insure air removal, at start-up of liquid system, the serviceman should

a. open all float vents.
b. loosen the collector connector.
c. check the system after a week's operation.
d. systematically open all bleeder valves.

69. Sensors function because

a. water or air pass over them.
b. of the kind of controller used with them.
c. heat changes in their electrical resistance.
d. of reasons not listed.

70. To balance an air solar heating system, servicepersons do *not* need to

a. review the shop drawings.
b. obtain pump performance data.
c. adjust dampers.
d. have manufacturer's recommendations.

71. The most difficult liquid storage tanks to seal are

a. concrete.
b. fiberglass.
c. glass-lined.
d. galvanized steel.

72. Checking the getter column often involves

a. adding lubricants.
b. changing aluminum strips.
c. cleaning the bowl.
d. adjusting the flow rate.

73. A system may be out of adjustment if

a. its ability to heat is decreasing.
b. the heat is uneven.
c. operating costs rise.
d. all of the above occur.

74. To keep from contaminating potable water, a solar system needs

a. a pressure relief valve.
b. a back-flow check valve.
c. a balancing valve.
d. a shut-off valve.

Be sure your name and address are on your exam before mailing!

Answer Key
To Progress Review Questions

Locate the specific Progress Review. Alongside the question number you'll find the correct answer.

If any of your answers do not agree with those listed here—first, reread the question; next, refer back to your textbook; finally, if you still disagree or fail to understand to your satisfaction, fill out one of the student assistance forms provided with your course materials and mail it to your instructor. A detailed explanation will be sent to you as soon as possible.

Lesson One

1. T
2. T
3. F
4. F
5. F
6. F
7. T
8. F
9. F
10. T
11. F
12. T
13. T
14. T
15. F
16. T
17. F
18. T
19. F
20. F
21. passive
22. greenhouse
23. air, liquid
24. black, absorbing
25. radiation, conduction, convection
26. conduction
27. during
28. ¾" to 1½"
29. five feet
30. leakage, plumbing connections
31. heat pumps, electric resistance heaters
32. refrigeration
33. absorption
34. compressor, condensor, expansion valve, evaporator
35. no, maintenance
36. 50-80
37. building design long term payout maintenance, repair, safety
38. d
39. d
40. b

Lesson Two

1. T
2. T
3. F
4. F
5. F
6. F
7. T
8. T
9. T
10. F
11. T
12. fossil
13. ultra-violet, visible, infrared
14. BTU/ft^2
15. 3.69
16. ultra-violet
17. IR
18. infrared
19. lower, reduces
20. greater
21. 25°, 75°
22. noon time
23. northern
24. south
25. the latitude, 15°
26. 15°
27. advance, one
28. c
29. b
30. b
31. c
32. c
33. a
34. a

Lesson Three

1. T
2. T
3. F
4. F
5. T
6. T
7. T
8. F
9. T
10. F
11. T
12. F
13. F
14. F
15. F
16. F
17. F
18. T
19. F
20. T
21. F
22. F
23. T
24. F
25. T
26. T
27. T
28. T
29. concentrating, flat plate
30. air, liquid
31. covers, absorber plate, heat transfer tube, insulation frame
32. b
33. d
34. b
35. d
36. b
37. b
38. d
39. see Figure 3-8

Lesson Four

1. T
2. T
3. F
4. F
5. F
6. T
7. F
8. F
9. F
10. T
11. F
12. T
13. F
14. T
15. T
16. T
17. T
18. F
19. F
20. T
21. F
22. phase change system
23. 188
24. thermosyphon, domestic hot water
25. water, rock
26. building, collector
27. electrolysis
28. concrete
29. ¾" to 1½"
30. vertical, horizontal
31. d
32. b
33. a
34. b
35. a
36. b
37. A. water is abundant
    B. water absorbs heat readily
    C. minimal space requirements
38. A. the system must be insulated
    B. overheating may occur
    C. there may be water leakage problems
    D. piping can corrode
    E. inspecting for leaks in inaccessible places
39. A. the system requires little maintenance
    B. leaks can be stopped easily
    C. warm air is easily connected to present heating systems
    D. rocks hold heat longer than water
40. A. they must be large compared to water units
    B. pebbles must be washed
    C. ductwork is bulky and occupies much space
41. A. concrete
    B. steel
    C. fiberglass
42. -22°F
43. 7°F
44. 54.6°F

Lesson Five

1. T
2. F
3. F
4. T
5. T
6. T
7. T
8. F
9. T
10. T
11. F
12. F
13. F
14. T
15. F
16. T
17. T
18. F
19. T
20. F
21. T
22. T
23. F
24. collectors, heat storage units
25. gallons per minute
26. anti-freeze, or special fluid, a drain-down cycle
27. shell, tube
28. static, velocity, total
29. system, fan
30. controller, actuator
31. collector, storage unit
32. conventional heat source
33. nickel wire
34. thermal conducting compound
35. solenoids
36. damper, solenoid
37. electromagnetic
38. expansion tank
39. balancing valves
40. dielectric unions
41. A. Pressure reducing valve
    B. Check valve
    C. Globe valve
42. A. Dirty filters
    B. Damper adjustment
    C. Basic alterations
43. d
44. a
45. a
46. See Figure 5-3

Lesson Six

1. T
2. F
3. T
4. F
5. F
6. T
7. T
8. F
9. F
10. d
11. d
12. a
13. c
14. b
15. d
16. d
17. a
18. c
19. 731.7 sq ft.
20. SMACNA Installation Standards
21. A. each procedure is based on different assumptions
    B. Must be thoroughly acquainted with the assumptions and how they differ from the parameters of his specific application
22. Any ten of the following solar system fixed initial cost installed cost per square foot of collector loan interest rate loan term loan down payment property tax rate income tax rate maintenance costs insurance rates property tax rates fuel costs inflation
23. A. 55
    B. $1000
    C. 2%
24. A. $6700
    B. 400
    C. 72
    D. 16.3
25. A. Shell and tube
    B. U-type
    C. Helical
26. $75 \times 0.0025 \times 145 = 2.72$ gal

Lesson Seven

1. F
2. T
3. T
4. T
5. F
6. F
7. F
8. F
9. T
10. T
11. T
12. c
13. d
14. d
15. a
16. A. Heating from the collector
    B. Heating from storage
    C. Heating from auxiliary
    D. Storing heat
    E. Heating domestic hot water (DHW)
17. opposite
18. A. air pressure in the system is higher
    B. there is more ducting
    C. the system runs more hours
    D. more ducts through unheated space
19. belt
20. live rubber seals
21. A. storing heat
    B. heating from collector
    C. heating with auxiliary

Lesson Eight

1. T
2. F
3. T
4. T
5. T
6. T
7. b
8. a
9. d
10. b
11. d
12. d
13. (Any two of these four):
    A. Variance of water temperature
    B. Design problems due to fact that storage tank must be above collector.
    C. Inability to use collector where temperature drops below freezing
    D. Safety valves necessary to allow excess pressures to escape
14. pressure/temperature relief
15. A. Collector
    B. Temperature sensor
    C. Pump
    D. Check valve see Figure 8-3
16. 8.33x70x(155-45) = 64,141

Lesson Nine

1. F
2. F
3. F
4. T
5. T
6. T
7. F
8. T
9. T
10. T
11. F
12. T
13. F
14. T
15. T
16. T
17. F
18. F
19. T
20. T
21. F
22. F
23. T
24. T
25. T
26. F
27. retrofitting
28. water, container
29. collector tilt angle
30. air vent
31. copper, high temperature plastic
32. volume of fluid, temperature rise
33. getter column
34. A. sheathing
    B. felt paper installation
    C. cutting piping openings
35. A. soldering
    B. threading
    C. clamped rubber hoses
36. A. direct return
    B. reverse return
    C. series
37. A. a blower
    B. motorized dampers
    C. 24-volt controller
    D. optional DHW preheat coil
38. A. low thermal conductance
    B. high resilience
    C. resistant to fire, insects, etc.
    D. a high melting point
    E. low bulk density
    F. a surface resistant to abrasion
39. b
40. a
41. d
42. d
43. c

Lesson Ten

1. T
2. T
3. F
4. T
5. T
6. T
7. T
8. T
9. T
10. F
11. T
12. T
13. F
14. T
15. F
16. T
17. T
18. F
19. burns, electrical shock
20. 24, sensors, relays, thermostats
21. open all bleed valves
22. balancing valve
23. loose connector, thermal conducting compound
24. work sheets
25. pressure build-up behind the glass covers
26. outgassing
27. materials, workmanship
28. 50%
29. getter column
30. 160
31. A. charging the system
    B. testing control modes
    C. taking various measurements
32. A. air filters
    B. liquid filters
    C. antifreeze concentration
    D. blower drive belts
    E. pumps
    F. liquid levels
33. A. electrical controls
    B. plumbing connections for DHW
    C. air diverting dampers
    D. blower
    E. blower motor
34. A. verify temperature differences
    B. check service voltage
    C. disconnect the collector lead wire to simulate high or low temperatures
    D. check wire around the service switch
35. A. note the complaint
    B. determine the symptom
    C. check the cause of each symptom
    D. remedy the trouble
36. A. part failure
    B. improper adjustments
    C. poor construction
    D. poor design
37. A. rotating valve anemometer
    B. velometer
    C. pitot tube
    D. pressure gauges (for example manometer)
    E. thermometer
    F. tachometer
    G. volt-amp meter
38. e
39. d
40. d

Lesson Eleven

1. T
2. F
3. T
4. F
5. T
6. F
7. T
8. F
9. T
10. F
11. T
12. T
13. F
14. T
15. T
16. F
17. T
18. operational, maintenance
19. structural, vegetation
20. change the tilt angle
21. zoning
22. regulatory, compensatory
23. low cost loans, tax breaks, income, sales, real estate
24. full, limited, implied
25. A. design characteristics
    B. intent of the codes when written
    C. specific wording
    D. attitudes of local authorities
    E. cost of changing testing criteria
26. A. ignore the system
    B. treat the entire system as a hot water system
    C. limit assessments to installation costs
27. A. right to light
    B. freedom from glare
    C. nuisances
    D. building standards
28. a and c
29. d

* U. S. GOVERNMENT PRINTING OFFICE : 1978—261-238/191